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A NON-INVASIVE AND PATIENT-SPECIFIC METHOD TO ASSESS SPINAL STIFFNESS IN ADOLESCENT IDIOPATHIC SCOLIOSIS

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INTRODUCTION

Adolescent Idiopathic Scoliosis (AIS) is a three dimensional deformation of the spine which develops during adolescence and is associated with difficulties in carrying out physical activities (lifting, running, standing and carrying), with back pain problems and an affected self-image. Spinal fusion surgery is generally indicated when thoracic curve is expected to reach at least 50° by skeletal maturity. To plan the surgery and predict its outcome, spinal flexibility has to be evaluated pre-operatively.

Several techniques are used clinically to evaluate spinal flexibility such as side bending or fulcrum bending. All these methods use medical imagery to compare the shape of the spine before and after loading, but none report the amount of forces used to provoke the observed motion. Therefore, only reducibility (change of spine shape) can be determined and not the flexibility of the spine, which could explain the large variability in surgical planning proposed by several experts for the same patients [Robitaille, 2007].

METHOD

For these reasons, an alternative pre-operative test has been developed, which combines an axial suspension of the patient with inverse finite element calculations [Büchler, 2014]. The Spinal Suspension Test is based on the application of an axial traction force on the patients' spines using a commercial head halter. The three-dimensional displacement of the vertebras is assessed with calibrated orthogonal radiographic images. The spinal shape is measured before and after application of a load corresponding to 30% of the patient's body weight. A numerical model of the spine is proposed to quantify the patient-specific mechanical properties. The model consists of rotational springs to model the flexible components of the spine. Three linear spring were used for each segment to represent the spinal flexibility along the main anatomical directions: flexion, axial rotation and bending. The vertebrae were considered as rigid bodies. The boundary conditions correspond to the experimental test: the lower vertebra has been fixed while a vertical force was applied to the most cranial vertebra. The Nealder-Mead optimization algorithm was used to find the stiffness parameters which best match our experimental measurements.

RESULTS

The Spinal Suspension Test has been applied on 5 AIS patients. For all these patients, a reduction of the curve has been observed during the traction test. In addition, the displacement of the vertebras induced by the loading was in average 12 times larger than the three-dimensional reconstruction precision. The parameter identification showed a prediction error on the vertebral position less than 5[mm]. In addition, important variations of the stiffness parameters were observed between patients, while being comparable with previous intra-operative measurements [Reutlinger, 2012]

DISCUSSION

Since the spinal shape and mechanical properties showed important variation across patients, this quantitative information provided by the proposed pre-operative test is critical for the development of planning solutions that consider patient-specific biomechanics. Such tools will become increasingly important in the future due to the ever-increasing complexity of the surgical instrumentation and procedures and to provide a better understanding of the complex biomechanical properties of the spine.

REFERENCES

- *Büchler et al, Eur Spine J, 2014*
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- *Robitaille et al, Eur Spine J, 16:1604–14, 2007*